

5 **Patent Claims**Method and Circuit Arrangement for Non-destructive Examination  
of Objects by Means of Ultrasonic Waves

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1. A method for processing signals which are generated during the non-destructive examination of objects (12, 24), e.g. pipes or sheet metal, by reflection of ultrasonic waves at defect locations (20, AF) of the structure of the object (12, 24), comprising the steps of:

- emission of a complete wave front onto at least one section of the object (12, 24) to be examined by means of a plurality of independent transmitter elements (EL1 - ELN),
- reception of a wave reflected by the structure of the object by means of a plurality of receiver elements (EL1 - ELN) which are independent of one another,
- digitalizing the signals received from the receiver elements (EL1 - ELN),
- storage of the digitalized signals according to amplitude and propagation time in a storage element (SP),

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characterized in that the defect locations (20) are detected by a phase-locked addition of the stored amplitude values along a propagation time.

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2. The method according to claim 1, characterized in that

5           to identify a defect location (outer defect) (20, AF) on  
an outer surface (54) of the object (12, 24), the point-  
wave signals passing from the defect location (20, AF) are  
evaluated.

10    3.    The method according to claim 1 or 2,  
characterized in that  
the defect location (AF) on the outer surface of the  
object (12, 24), i.e. the surface facing the probe (14,  
26, 28), is effected by an addition of those amplitude  
15    values stored in the storage module (SP) which are derived  
from the point-wave signals proceeding from the outer  
defect (AF).

20    4.    The method according to at least one of the preceding  
claims,  
characterized in that  
the addition extends at a right angle or essentially at a  
right angle to the interference pattern of the received  
amplitude values of the point waves of the outer defects  
25    (AF).

30    5.    The method according to at least one of the preceding  
claims,  
characterized in that  
the outer defect (AF) takes place by a comparison of the  
sum signal determined during the phase-locked addition of  
the stored amplitude values along a propagation time with  
the sum signal determined during the addition of the  
amplitude values of the interference pattern, an outer  
35    defect (AF) being present if both sum signals indicate a  
defect location (coincidence method).

- 5 6. The method according to at least one of the preceding  
claims,  
characterized in that  
the individual transmitter elements (EL1 - ELN) are  
controlled in a time-delayed manner (phasing) to set a  
10 beam angle  $\alpha$  adapted to the test conditions, e.g. type of  
defect, size of defect, type of material, material form.
7. The method according to at least one of the preceding  
claims,  
15 characterized in that  
a propagation time dependent amplitude correction of the  
sum signal determined during the addition is performed to  
identify the location of the defect.
- 20 8. The method according to at least one of the preceding  
claims,  
characterized in that  
the received signals are filtered, preferably wavelet  
filtered, after their digitalization for the data  
25 reduction.
9. The method according to at least one of the preceding  
claims,  
characterized in that  
30 the contour of a surface (68, 70) of the object (12, 24,  
66) to be examined is recorded and stored,  
the independent transmitter elements (EL1 - ELN) are  
controlled in a time-delayed manner in such a way that the  
emanating wave front (74) extends parallel or  
35 approximately parallel to the contour of the surface (68,  
70) of the object (66) and the waves reflected by the  
object (66) are received in a time-delayed manner and

- 5           generate an essentially planar interference pattern (76).
10.   A method for the non-destructive examination of a contour  
of an object (12, 24, 66) by processing signal waves which  
are generated by reflection of ultrasonic waves at defect  
10       locations (20, AF) of the structure of the object (12,  
24), comprising the steps of:
- emission of a complete wave front onto the at least  
one contour of the object (12, 24, 66) to be examined  
15       by means of a plurality of independent transmitter  
elements (EL1 - ELN),
  - reception a wave reflected by the structure of the  
object by means of a plurality of receiver elements  
(EL1 - ELN) which are independent of one another,
  - 20       -       digitalizing the signals received from the receiver  
elements (EL1 - ELN),
  - storing the digitalized signals according to  
amplitude and propagation time in a storage element  
(SP),
- 25       characterized in that  
the contour of a surface (68, 70) of the object (12, 24,  
66) to be examined is recorded and stored,  
the independent transmitter elements (EL1 - ELN) are  
30       controlled in a time-delayed manner in such a way that the  
emanating wave front (74) extends parallel or  
approximately parallel to the contour of the surface (68,  
70) of the object (66) and the waves reflected by the  
object (66) are received in a time-delayed manner and  
35       generate a substantially planar interference pattern (76).
11.   The method according to at least one of the preceding

- 5       claims,  
characterized in that  
the contour of the object (66) is determined by emitting,  
for example, a planar wave front (64) onto the contour to  
be examined,
- 10       the waves reflected by the contour of the object (66) are  
received, digitalized by means of the plurality of  
receiver elements (EL1 - ELN) which are independent of one  
another and the digitalized signals are stored in the  
storage element (SP) at least according to propagation
- 15       time,  
the contour of the object is computed from a defined  
distance (A) of the probe to the object (66) and the  
different propagation times of the received signals.
- 20   12. The method according to at least one of the preceding  
claims,  
characterized in that  
an interference pattern (76) determined from the received  
signals is compared with a desired pattern and that, when
- 25       there is a deviation from the desired pattern, a renewed  
contour measurement is performed.
13. The method according to at least one of the preceding  
claims,
- 30       characterized in that  
a subsequent determination of the contour of the object to  
be examined takes place during an measuring process.
14. The method according to at least one of the preceding  
claims,
- 35       characterized in that  
the wave front (74) extending parallel or essentially

5 parallel to the contour of the object (66) to be examined is generated by a time-delayed emission of sound pulses.

15. The method according to at least one of the preceding claims,

10 characterized in that

the received planar interference pattern (76) is received by time-delayed actuation of the receiver elements (EL1 - ELN) which are independent of one another in dependence on the contour values stored in the storage unit.

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16. A circuit arrangement (22) for processing signals which are generated during the non-destructive examination of objects, e.g. pipes, sheet metal, by reflection of ultrasonic waves at defect locations of the structure of the object, comprising a signal recording unit (38) with a pulse generator (PE) for actuating transmitter/receiver elements (EL1 - ELN) for emitting a complete wave front and for switching the transmitter/receiver elements (EL1 - EL2) to receive, wherein a multiplexer (MUX) is provided via which analog signals applied to the receiver elements can be transmitted to A/D converters (AD1 - ADN), the outputs of which are connected to a storage element (SP) for storing digitalized signals,

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characterized in that

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the digitalized signals are stored in the storage element (SP) with respect to their signal amplitude and propagation time and a summing element (SUM) for the phase-locked addition of the amplitude values stored in the storage element (SP) is arranged in tandem behind the storage element (SP) and a signal which can be evaluated with respect to the defect location (20) is applied to an output of the summing circuit (SUM).

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17. The circuit arrangement according to claim 16, characterized in that
- 10 the output of the summing element (SUM) is preferably connected via an interface I with an evaluation circuit (46) in which an output of the summing element (SUM) is connected with a signal processing circuit (46) which has one or more evaluation modules (F1, F2) for the further assessment and evaluation of the signal applied to the output of the summing element (SUM).
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18. The circuit arrangement according to claim 16 or 17, characterized in that
- 20 the evaluation module (F1, F2) has a coincidence circuit for comparing the sum signals during a phase-locked addition of the amplitude values along a propagation time with the sum signals during addition of the amplitude values of the point-wave signals of outer defects.
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19. The circuit arrangement according to claim 16 to 18, characterized in that
- the probe (14, 26, 28) is configured as a Phased Array Transducer.
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20. The circuit arrangement according to claim 16 to 19, characterized in that
- the transmitter/receiver elements (EL1 - ELN) can be controlled simultaneously or in a phase-shifted manner (phasing).
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21. The circuit arrangement according to claim 16 to 20, characterized in that
- the transmitter/receiver elements (EL1 - ELN) are made as

5 a unit.

22. The circuit arrangement according to claim 16 to 21,  
characterized in that  
the transmitter elements and receiver elements are made  
10 as separate units.